IMPACTS OF RACE AND GENDER ON EXERTIONAL HEAT ILLNESS

AMONG U.S. ARMY SOLDIERS; 1980-1998

A Thesis Presented

by

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Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

May 2002

Biostatistics and Epidemiology

ACKNOWLEDGMENTS

ABSTRACT

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MAY 2002

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Previous studies have suggested that blacks and men may have greater risks of exertional heat illnesses than whites and women. We report on a pilot, retrospective, case-only study of 2,780 military heat illnesses. ICD-9-CM codes from the Total Army Injury and Health Outcomes Database[19] hospital records were used to identify all cases of heatstroke and heat exhaustion occurring among active-duty U.S. Army soldiers between 1980 and 1998. Cases were stratified by the maximum daily temperature for the incidence date of the case; cases occurring on days when the temperature exceeded the cautionary temperature of 80°F were considered heat induced and cases occurring on days cooler than that threshold were considered exertional. We found a significantly higher risk of cool temperature heat illnesses among blacks in comparison to whites after adjusting for age and gender [OR=1.31, 95%CI (1.04-1.66)]. In contrast, males did not have a significantly higher risk estimate for cool temperature heat illnesses compared to females [OR= 0.91, 95%CI (0.69-1.20)]. Without a disease-free control group for comparison, our results may not accurately describe natural etiologic associations. Interpretations of these results must be made only with the assumption that the exposure of interest is unrelated to our pseudo-control group.

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CHAPTER I

INTRODUCTION

A. Statement of Introduction

At the forefront of military preparedness is the assurance of a healthy fighting force. Under combat conditions, unexpected illnesses and injuries can wreck havoc on tactical operations. Heat illnesses in particular can occur suddenly. The ability to identify susceptible populations and to prevent these illnesses can be instrumental in minimizing loss of personnel.

B. Risk Factors for Heat Illnesses

Among heat illnesses, heatstroke is the most severe and causes death in 17% to 80% of its victims. It is characterized by a severe dysfunction of the thermo-regulatory system leading to neurologic decompensation (5). The Centers for Disease Control and Prevention (CDC) reported 371 deaths per year as the US annual average attributable to excessive heat exposure between 1979-1997 (13). The CDC recognizes age (e.g. the elderly), chronic health conditions (e.g., cardiovascular or respiratory diseases), mental illness (e.g., schizophrenia), social circumstances (e.g., living alone) and other conditions that interfere with the ability to care for oneself as the primarily recognized risk factors for heat illnesses (13). Other suspected risk factors include alcohol consumption, which may cause dehydration, previous heatstroke, physical exertion in exceptionally hot environments, and medications that interfere with the body's heat regulatory system, and/or have anticholinergic effects (13).

C. Heatstroke Classification

Heatstroke is diagnosed by an internal body temperature in excess of 105°F and is responsible for the vast majority of hyperthermia deaths. Two significantly different etiologies for heatstroke can be defined by the heat source. *Classic* heatstroke occurs by external heat overload such as occurs in a poorly ventilated car during a summer heat wave. Infants, toddlers, and the elderly characteristically function with impaired cooling mechanisms and/or weakened cardiovascular systems. This may predispose them to have difficulty compensating for extreme environmental heat loads. In contrast, *Exertional* heatstroke occurs in conjunction with an extreme amount of muscular (internal) heat production and victimizes any age group especially healthy and active athletes or military personnel. The physiologic mechanisms for disease onset are similar in both groups, yet we can identify two distinctly separate populations at risk.

D. Heat Exhaustion Classification

Heat exhaustion is less severe than heatstroke, and is not considered an actual intermediate stage to heatstroke development (9). It is distinguished from heatstroke by an internal temperature less than 105°F. Human exertion studies under laboratory conditions simulating intense heat and humidity have failed to produce heatstroke as an extention of continued heat exhaustion (9). Whereas heat exhaustion is the result of dehydration or salt depletion, heatstroke is a failure of the body's physiologic cooling mechanisms. Heat exhaustion can lead to hospitalization if the victim fails to cease activity and seek treatment. This can lead to circulatory collapse and a more

complicated medical condition sometimes mistaken for heatstroke. Although heat exhaustion diagnoses are not typically dichotomized by heat load source as heatstroke is, for the purposes of this study we will distinguish between classic and exertional heat exhaustion based on the maximum daily temperature on the day of incidence, as markers of the probable heat load source.

E. Study Purpose

Population-based, heat wave studies have identified the majority of risk factors recognized by the CDC. These studies have traditionally studied classic heatstroke hospitalizations and deaths because of their ease of identification. In contrast, case-control studies of military personnel and athletes have often been limited to heat exhaustion. Results of both population based classic heatstroke and military/athlete heat exhaustion studies have suggested race and gender as potential risk factors. A specific study of these factors is supported by recent Alabama state mortality rates, which identified higher rates of heatstroke fatality among men and blacks (14). This project contributes to the heat illnesses literature by utilizing an expansive administrative database to identify the roles of race and gender on heatstroke and heat exhaustion incidence in the U.S. Army.

Temperature and humidity extremes are known to increase the risk of heat illnesses. This is especially true during vigorous exercise. Recent literature has suggested that as many as 62% of heat illness cases in the military may occur at lower than cautionary environmental conditions (15). Heat illnesses that occur on days with cooler temperatures may thus be used to identify exertion related heat illnesses and/or

individuals with a potential predisposition. Risk factors specific to those individuals may therefore be identified and utilized in future administrative heat illness prevention plans.

The hypothesis of this study is that black soldiers and men have higher rates of exertional heat illnesses, defined as heat illnesses occurring at temperatures less than or equal to 80°F, than they do classic heat illnesses occurring at temperatures greater than 80°F. In so doing, we evaluate whether black soldiers and males are predisposed to heat illnesses in comparison to white soldiers and females.

CHAPTER II

REVIEW OF THE LITERATURE

A review of epidemiologic studies found many city, mortality, heat-wave case-control studies. These studies invariably measure an excess of classic heatstroke outcomes. In contrast, military based epidemiologic studies rarely identify fatal heat illnesses, suggesting a predominance of heat exhaustion. Military studies have traditionally not identified enough heatstroke cases to statistically distinguish heatstroke and heat exhaustion as separate outcomes.

A. 1980 Missouri Heat Wave Study

In 1982, Kilbourne and others (5) analyzed classic heatstroke during the 1980 heat wave in St Louis, and Kansas City. They found a remarkable 208 cases of adult heatstroke from acute-care hospitals and from medical examiner records of both cities. Of the 208 cases, 156 (73 fatal) were entered into the study. Three controls were individually neighborhood matched to each case based on age (within 5 years) and sex. When neighborhood matches were unavailable, they sacrificed geographical similarity for matching on only race and socioeconomic status.

A stepwise selection procedure of 123 demographic, epidemiologic, and clinical data factors accompanied the logistic regression model resulting in seven important risk factors for heatstroke death. Inverse associations were found for dichotomous factors including ability to care for self (RR=0.20, 95% CI=0.07-0.60), reduction of physical activity in heat (RR=0.19, 95% CI=0.08-0.43) and spending increased time in air-conditioned places (RR=0.26, 95% CI=0.07-0.93). A positive

association was reported between fatal heatstroke and history of alcoholism (RR=15.02, 95% CI=1.87-120.43). Risk of heatstroke death for persons without home air-conditioning was 49.4 times the risk of people with 24-hour/day air-conditioning (95% CI=1.6-286.4). Inverse associations were found for each incremental 1 hr/day increase in air-conditioning exposure (RR=0.85, 95% CI=0.79-0.92), and for increases within the four levels of characteristic physical activity ranging from bedfast to strenuous exercise (incremental RR=0.42, 95% CI= 0.22-0.80). People that used major tranquilizers and anticholinergic medications had 2.98 times the risk of heatstroke death than people that did not (95% CI=0.97-9.18).

Risk factors for nonfatal heatstroke were similar and specifically included dichotomous variables of increased time spent in air-conditioned places (RR=0.27, 95% CI=0.11-0.65), ability to care for self (RR=0.18, 95% CI=0.07-0.49), and taking extra liquids on days with higher heat (RR=0.27, 95% CI=0.11-0.66). Incremental inverse comparisons relevant to nonfatal heatstroke included hours/day of home air conditioning 0.93 (0.89-0.98), and extent of tree or shrub growth (4 levels ranging from none to heavy growth) surrounding the residence 0.52 (0.30-0.93). Height of residence above the ground floor showed an incremental positive association of 1.59 (1.24-2.03). Air conditioning and upper socioeconomic conditions are often correlated. This can artificially inflate the relation between high socioeconomic status and better quality of health care with respect to heat illnesses. Race was included in the initial list of potential risk factors and later eliminated from the models due to a lack of significance. Neighborhood matching could have easily been responsible for this lack of significance.

B. Marine Corps Risk Factor Study; 1988-1992

Gardner and colleagues (7) published a case-control study on heat illnesses in male Marine Corps recruits at Parris Island, SC between 1988-1992. Recording 528 heat illnesses, females were excluded because they represented only 10% of the cases. Of males, only 11% were hospitalized. Controls were matched on initial training platoon to insure equal risk of disease. Cases were identified from the Marine Corps Automated Recruit Management System (ARMS).

Odds ratios matched on training platoon identified a 60% increase in risk (95%CI 1.2-2.1) for black versus white marines. Higher risk for exertional heat illnesses was also identified for subjects with shorter height, heavier weight, higher BMI, slower run-times, fewer pull-ups, and fewer sit-ups. After step-wise multivariate analysis, only race, BMI, and physical fitness tests remained significant as independent risk factors for exertional heat illnesses among US Marine Corps recruits. The low rate of hospitalizations suggests that heatstroke was probably a very rare outcome in this study. Because heat exhaustion is not an intermediate to heatstroke (9), these results should be interpreted as a reflection of exertional heat exhaustion etiology, and only cautiously applied to heatstroke.

C. Marine Corps Heat Illness and Climatologic Analysis; 1982-1991

Kark and others (15) published data on the basic training Marine Corps recruits from Parris Island, SC between 1982-1991. Utilizing the Automated Recruit Management System database (ARMS), 1,454 heat illnesses and their respective incidence rates (per 1000 person-months) were calculated. They found an average of

145 incidents per year. Males accounted for 1,293 (89%) cases, while 161 (11%) were female. Of the entire 1,454 cases, 141 (10%) were hospitalized and all hospitalizations were male. If female heat illnesses had experienced the same hospitalization rate as males, one would have expected 18 female hospitalizations. This supports the idea that males may be at higher risk for serious cases of heat exhaustion and/or exertional heatstroke.

Heat illness rates increased daily in conjunction with an increase in the Wet Bulb Globe Temperature Index (WBGT) until the index reached 80°F. WBGT is a weighted temperature index based on air temperature, air movement, humidity and radiant heat exchange. Training restrictions are administratively imposed to minimize heat illness morbidity upon the WBGT exceeding 80°F. Unexpectedly, 62% of the cases had not been exposed to environmental flag conditions (WBGT ≥ 80°F) on the day of incidence, but were exposed on the day prior to their illness. In fact, many cases occurred primarily during the cooler early morning hours. This may be explained by military policy to schedule the most strenuous physical exercises for the morning to avoid the hotter hours of the day. The authors state that risk for exertional heat illnesses increases markedly at WBGT levels well below those at which flag conditions (i.e. training restrictions) begin, particularly for high metabolic rate activities such as running, and that prior-day heat stress exposure might be important. Further comments included the idea that gender differences could be explained by physiologic and/or behavioral differences yet the authors maintain that the higher rate of male, heat illness hospitalizations may be a simple artifact of more rigorous physical training among males.

D. Alabama Temperature-Related Mortality Study

Taylor and others, 2000 (14), published Alabama mortality rates that suggest potential gender and racial associations with fatal heatstroke. Vital statistics and ICD-9 codes were used from the Alabama Department of Public Health to identify all deaths between 1987 and 1998 caused by heat or cold.

Heat-related deaths in Alabama were found to be higher across all race/sex groups than rates for the United States overall. Mortality rates per 100,000 were calculated from population data obtained from the US Bureau of Census and the CDC Compressed Mortality Databases. Black men, black women, white men and white women had mortality rates of 14.49, 5.89, 2.96 and 1.24 respectively. Rate ratios can be calculated from the published mortality rates and show an increased risk for all blacks versus all whites of 4.85. A gender difference is also apparent in the calculated rate ratio for males versus females of 2.45. Fatalities were predominantly classic heatstroke as determined from age stratified mortality rates and similar results have been previously reported (16, 17, 18). The authors suggested that higher rates of heat-related death among blacks could be the result of overall lower socioeconomic status (SES) among blacks in Alabama. This is possible as Kilbourne suggested by linking SES and air-conditioning access, and air-conditioning with heat illness risk (5). Taylor also commented that higher rates of heat-related deaths in males could be a result of greater alcohol consumption (14). The CDC lists alcohol consumption as a potential risk factor for heat illnesses due to dehydration (13).

E. Literature Summary and Present Study Support

In light of the potential severity of certain heat illnesses, public health officials may be interested in the identification of high-risk populations. Heat illness studies have suggested potentially higher risk estimates for men and blacks, yet few studies exist with a priori hypotheses focusing on race or gender and their specific relation to exertional heat illnesses. Exertional heatstroke has also yet to be studied in depth due to a very low incidence rate thus leaving a sizeable gap in the research considering the potential severity of the disease.

This study is intended to supplement current knowledge by focusing on the effects of race and gender on exertional heatstroke and heat exhaustion in a military population. The low incidence rate of heatstroke has been addressed by incorporating all cases of heatstroke and heat exhaustion in the U.S. Army over an eighteen-year span. We hypothesize that black soldiers and males in the U.S. Army, between 1980-1998, would have greater rates of exertional heatstroke and heat exhaustion (defined by temperatures below 80°F) than would white soldiers and females. This would suggest that blacks and male soldiers are more predisposed to heat illnesses than their white and female counterparts are. These associations are expected to persist after controlling for average levels of exertion (military occupational specialty), age, geographic location, military rank and health-related factors (smoking rates, alcohol intake, and body mass index).

CHAPTER III

METHODS

A. Study Design

This study utilized a case-only design (i.e. case-case) to evaluate the relation between race and gender on the incidence of exertional heatstroke and heat exhaustion in the United States Army from 1980 to 1998. Case-only analyses identify the relative risks specific to exertional heat illnesses among blacks and men compared to whites and women rather than for all heat illnesses. The Case-case comparison was employed to avoid the difficult selection of applicable controls available in an administrative database designed strictly to identify medical cases. A traditional case-control study would have been a better design choice if good control assignments were possible.

Heat illness cases were dichotomized about the temperature of 80°F, a temperature cut-point at which standard military policy dictates a restriction of exertion levels to prevent heat illnesses. Cases occurring on days when the maximum temperature remained less than or equal to 80°F were compared against cases that occurred on days when the maximum temperature exceeded 80°F. Our assumption is that cases occurring at cooler temperatures have a much higher chance of being exertionally induced compared to classic heat illnesses. Because these cases occurred under less stressful environmental conditions, they may also identify individuals more predisposed to heat illnesses. In this case, our results would be useful in identifying high-risk populations.

B. Database Description

We identified 3,837 incident cases from the Total Army Injury and Health Outcomes Database[19] (TAIHOD) using the PASBA, hospitalization component of the TAIHOD with ICD-9-CM codes. The specific diagnoses evaluated in this study included Heatstroke (ICD-9=992.0, n=708), Anhydrotic Heat Exhaustion (992.3, n=351), Heat Exhaustion due to salt depletion (992.4, n=68), and Unspecified Heat Exhaustion (992.5, n=2,710). In restricting potential subjects to their first reported heat illness, we omitted 105 cases. Linking personnel records to hospital data resulted in the loss of 226 cases and another 709 cases were lost due to the unavailability of temperature data. Maximum daily temperature readings from the National Climatic Data Center online data source was only available for those soldiers where the military hospital was in close proximity to a city or major airport. Seventeen warrant officers were omitted because of their unique daily activities and pay grade/rank scale in relation to officers and enlisted men, leaving a total study size of 2,780 heat illnesses.

Data was extracted from the TAIHOD to identify our study population of interest. The TAIHOD is a versatile system originally established to study special health risks in the growing female population in the military, and links multiple personnel and health datasets from many agencies of the U.S. Defense Department[19]. The database links three general categories of data: demographics, outcomes (hospitalizations, lost-time injuries, permanent disabilities, and fatalities), and self-reported health habits and risk-taking behavior, as reported by survey. All data components are linked by individual social security number. Our study uses data

from several TAIHOD sources, including the Patient Administration Systems and Biostatistics Activity database (PASBA), Defense Manpower Data Center (DMDC), Health Risk Appraisal Survey database (HRA) and the Health Enrollment and Assessment Review database (HEAR). Climate information, specifically maximum daily temperature, was obtained from the National Climatic Data Center (NCDC) offering free online climate data for national and worldwide areas[20].

Assessment of the maximum daily temperature experienced by each case on the event date and geographic location of the event was an integral part of this study. The data collection involved individual linking of the date of the event, the reporting military hospital location, and the closest geographical NCDC participating data collection center, commonly a large city or airport. These locations were grouped by state and then dichotomized by northern and southern states to control for geographic differences. Northern states with reported heat illnesses (n=251) included MA, NY, NJ, IN, IL, MO, KS, WA, and CO. Southern states included NC, SC, GA, AL, LA, KY, TX, OK, CA, and AZ (n=2,529 heat illness).

The exposure variables of interest were collected from DMDC self-reported demographic case records completed upon entry into the military. Racial groups were combined to form three categories: White, Black and Other. The original study proposal stated that we would also measure and study Hispanics separately, but due to the small number of Hispanic heat illness cases (n=90) they were combined into the category of the remaining ethnicities referred to as 'other.' Gender was assessed from the same demographic records as ethnicity, and simply dichotomized as male and female.

We collected information on several potential covariates including age, military career duration, rank/pay grade, military occupational specialty (MOS) and geographical region on the date of disposition. Whereas birth date and date of military career initiation are single events and widely available from multiple sources in the TAIHOD, military rank, MOS and assignment location may vary during a soldiers career. Rank and MOS were thus assessed for each case from the last 6-month DMDC follow-up report filed prior to each respective disease incidence. In a traditional case-control study, cases and controls require equal opportunity to experience the outcome excluding the exposure of interest (i.e. matching on temperature and activity). However, due to our case-only study design, all study subjects are incident cases, and we can thus analyze geographic location, length of military career, and military occupation as potential confounders.

Other variables measured included body mass index (BMI), alcohol consumption and tobacco use frequency. These behavioral questions were only available for those cases that completed a military Health Risk Assessment Survey (HRA)(n=203) or a Health Enrollment and Assessment Review Survey (HEARS)(n=31). The surveys were initially administered beginning in 1987 and were non-mandatory. They were commonly administered upon in-processing to a new unit, physical fitness tests, visit to outpatient/health clinics, and during routine, periodic physical exams. The sub-sample of soldiers having completed these surveys was small and not representative of the original study base (Tables 1 & 4). The surveyed population was therefore used strictly in an exploratory manner to assess the covariate effect of the health behavior variables.

C. Statistical Analyses

Creation of the study database, and statistical analyses was accomplished with the use of SAS v8 software. Odds ratios were calculated to evaluate the effects of gender and ethnicity on the risk of exertional heat illnesses as compared to classic heat illnesses, defined by the maximum daily temperature on the days of incidence. Odds ratios compared ratios of males to females, blacks to whites and other ethnicities to whites.

Multivariate logistical regression analyses adjusted the odds ratios for relevant risk factors and health behaviors. The evaluation of potential covariates employed the decision that confounders would be recognized by an alteration of the odds ratios by greater than 15% after insertion of individual risk factors into the logistic regression model. Each study population (heatstrokes, heat exhaustions, surveyed heat illnesses, and the total study population) is described by unadjusted, best and fully adjusted odds ratios (Table 7). Best odds ratios are risk estimates controlling for Age, Race or Gender and any significant confounders. Fully adjusted odds ratios control for all of the potential covariates regardless of their significance according to our 15% rule.

CHAPTER IV

RESULTS

A. Description of the Study Population

We report on 2,780 domestic, active duty service members of the United States Army. These soldiers were hospitalized for a heat illness between 1980 to 1998. During this time, 2,263 heat exhaustion and 517 heatstroke related hospitalizations were reported (Table 1). Of all cases, 85% (n=2,356) were men and 23% (n=637) were black (Table 1). Of the entire study population, the mean age was 23.5 (SD=5.83). Fifty-two percent of all heat illnesses occurred in soldiers younger than 23 years of age (Table 1). The largest military occupational group was the infantry and gun crews, with 29.3% (n=812) while officers accounted for 13% (n=364) of all represented military ranks (Table 1). Nearly 30% of all heat illnesses (n=832) occurred during the first year of a soldier's military career and only 9% (n=251) occurred in a northern state (Table 1).

Information on the health behavior variables cigarette usage, alcohol consumption and body mass index were available for soldiers who completed a health survey. The surveyed population (n=234) represented 8.4% of the total study population. Surveyed soldiers were slightly older having a mean age of 27 compared to 23.5. This can be expected to allow time prior to completing a health survey. Only 15.2% (n=7) of the surveyed soldiers suffering from an exertional heat illness had been enlisted less than 1 year compared to 27.5% (n=124) among the total study population (Table 2). Of the surveyed exertional heat illnesses, 78% (n=36) were male compared to 83.4% (n=376) among all heat illnesses (Table 2). Slightly more

surveyed, exertional heat illnesses were black (30.4%, n=14) compared to the overall study population (28.2%, n=127) (Table 2). Soldiers working in the Infantry and Gun Crews accounted for 17.4% (n=8) of the surveyed exertional heat illnesses compared to 26.6% (n=120) of the overall study population (Table 2). We also note that only 6.5% (n=3) of the surveyed exertional heat illnesses were First or Second level enlisted men/women compared to 31% (n=140) of the general study population.

B. Unadjusted Comparisons of Exertional and Classic Heat Illnesses

Among all heat illnesses, the unadjusted odds ratio specifies that blacks have a 39% higher risk of mild temperature heat illnesses than whites with 95% confidence (95% CI 1.11-1.76) (Table 3). Other ethnicities versus whites resulted in a non-significant odds ratio of 0.97. The unadjusted gender comparison suggested that men may be somewhat protected from mild temperature heat illnesses, though the odds ratio of 0.88 was non-significant (95% CI 0.67-1.43) (Table 3).

In the assessment of heat exhaustion cases apart from heatstroke cases, the unadjusted results are similar to those for all heat illnesses but with slightly greater estimates of the impacts of race and gender. The unadjusted odds ratio showed a significant, 44% higher risk of exertional heat exhaustion for blacks compared to whites (95% CI 1.10-1.88) (Table 4). Comparing other ethnicities to whites resulted in a non-significant, unadjusted odds ratio of 0.95 (Table 4). Males showed an odds ratio of 0.78 compared to females suggesting an even lower risk of heat exhaustion occurring in cooler temperatures, though results were still not statistically significant (95% CI 0.58-1.05) (Table 4).

When considering heatstroke cases separately, we observed that blacks had an unadjusted, non-significant 26% higher risk for exertional heatstroke in comparison to whites (95% CI 0.80-1.99) (Table 5). Other ethnicities were not significantly different from whites in the heatstroke analysis as evidenced by the unadjusted odds ratio of 0.96. The non-significant, unadjusted gender comparison of heatstroke cases, like the total study population, suggested that men have a lower risk of mild temperature heatstrokes than do women with an odds ratio of 0.86 (95% CI 0.40-1.83) (Table 5).

Soldiers that were administered a health survey, of which only 46 experienced a heat illness occuring at less than or equal to 80°F, gave less support for a racial impact on exertional heat illnesses. The black versus white unadjusted odds ratio was 1.16 with a 95% CI of 0.57-2.37 (Table 6). Other races versus whites showed an unadjusted odds ratio of 0.38 (95% CI 0.08-1.70) (Table 6). The unadjusted gender comparison within the surveyed population resulted in the first significant males vs. females odds ratio of 0.43, 95% CI (0.19-0.99) (Table 6).

C. Adjusted Comparisons of Exertional and Classic Heat Illnesses

After adjustments for age and gender by their addition into the multivariate logistic regression model, the risk of exertional heat illnesses was significant at a 31% risk in black vs. white soldiers (95% CI 1.04-1.66) (Table 7). The fully adjusted model for both heatstroke and heat exhaustion combined resulted in a significant odds ratio showing a 32% higher risk of exertional heat illnesses in blacks compared to whites (95% CI 1.05-1.71) (Table 7). Other racial groups combined compared to

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whites, after controlling for age and gender resulted in an odds ratio for all exertional heat illnesses of 0.98 (Table 7). Full adjustment for all potential covariates showed a 4% higher ratio for the other races vs. whites (95% CI 0.70-1.54) (Table 7). The comparison of males to females for all heat illnesses showed that the best fit model, controlling for age and race, attenuated the impact of gender on exertional heat illnesses (OR=0.91) (Table 7). However, the fully adjusted model suggested a modest increase in risk of exertional heat illnesses for males compared to females (OR= 1.07, 95% CI 0.79-1.45) (Table 7).

In the heat exhaustion analyses we found that controlling for age and gender attenuated our black versus white odds ratio from 1.44 (unadjusted) to 1.35 but maintained statistical significance (95% CI 1.02-1.78) (Table 7). After adjusting for all potential covariates the black vs. white odds ratio of 1.38 also remained significant with 95% confidence (95% CI 1.04-1.84) (Table 7). Comparisons of other races to whites were adjusted for age and gender and fully adjusted with odds ratios of 0.97 and 1.01 respectively. The risk of exertional heat exhaustion in males vs. females was attenuated after controlling for age and race to an odds ratio 0.82 (95% CI 0.60-1.11) (Table 7). Fully adjusting the male vs. female model for all potential covariates resulted in a nearly null odds ratio (OR= 0.95, 95% CI 0.68-1.32) (Table 7).

The unadjusted heatstroke odds ratio of 1.26 for blacks vs. whites was attenuated by 15% when we controlled for age, gender and military occupation (Table 7). The resulting odds ratio of 1.07 suggests that race may be unimportant in predicting exertional heatstroke specifically. Adjusted for age, gender and occupation, comparing heatstroke frequencies among other races to whites resulted in

an odds ratio of 0.93 (95% CI 0.44-1.95) (Table 7). Controlling for age, gender and occupation altered the unadjusted gender odds ratio of heatstrokes from 0.86 by 26% to 1.10 (95% CI 0.50-2.45) (Table 7). Daily activities, roughly measured here by occupation, may confound the associations of race and gender with exertional heatstroke incidence as observed above. The fully adjusted heatstroke models are reported for consistency with the other population analyses showing an odds ratio of 1.12 for blacks vs. whites with a 95% confidence interval of 0.67-1.87 and an odds ratio of 1.23 for males vs. females (95% CI 0.54-2.78) (Table 7).

D. Health Survey Multivariate Results

Soldiers that completed an HRA or HEAR health survey (n=234) offered us the opportunity to assess alcohol consumption, cigarette usage and body mass index in addition to the other potential covariates analyzed in this study. These factors could only be included in the multivariate analyses for this smaller surveyed population.

In the multivariate analysis of the surveyed population, controlling for alcohol consumption and gender significantly lessened the age-adjusted 18% higher rate of blacks to whites exertional heat illnesses ratio (Table 6) to an odds ratio of 0.93 (95% CI 0.44-1.97) (Table 7). Other racial groups compared to whites in the surveyed population had no change in the odds ratio after adjustment for age, gender and alcohol consumption (ORs=0.38, 95% CI 0.40-1.79) (Table 7). After adjusting for age, race and occupation, the males vs. females test statistic lost its significance (OR= 0.56, 95% CI 0.23-1.40) (Table 7). The fully adjusted models suggested protective

effects for blacks and for other racial groups combined vs. whites with odds ratios of 0.72 (95% CI 0.30-1.77) and 0.35 (95% CI 0.07-1.81) respectively. Comparing males to females in a fully adjusted multivariate analysis showed a modest reduction in risk for exertional heat illnesses among the surveyed males (OR=0.85, 95% CI 0.29-2.53) (Table 7).

CHAPTER V

DISCUSSION

A. Results Summary

The results of this study suggest that blacks may have a greater risk of cool temperature (exertional) heat illnesses than do whites. These findings were consistent with and without adjustment for many potential covariates including age, gender, military rank, geographical location, occupation and number of years in the army. The difference in the comparison of blacks to whites was the strongest in heat exhaustion specific analyses and very weak for models exclusive to heatstroke suggesting that blacks may be more predisposed to heat exhaustion than to all heat illnesses. These results should not be over-interpreted given the limitations of case-case studies, the modest magnitude of the odds ratios and the possible absence of important confounders from our analyses.

Gender specific analyses did not support the study hypothesis that males had higher risk of exertional heat illnesses. To the contrary, many models suggested that males in comparison to females had slightly lower rates of exertional heat illnesses. An exception to this was the heatstroke specific analyses in which men had a non-significant 10% higher risk of exertional heatstrokes compared to females after adjusting for age, occupation, and race. This association was further increased to a 23% higher risk after adjusting for all possible risk factors including rank, location and army career duration. However, as exertional heatstroke studies traditionally suffer from poor statistical power, our odds ratio too was not statistically significant.

In our attempt to examine the covariate status of several health behaviors such as cigarette smoking, alcohol consumption and BMI, we found that alcohol consumption was a significant confounder in our surveyed population of soldiers for the relations of all exertional heat illnesses with race (Table 6). This supports the CDC's alcohol classification as a potential risk factor (13). In fact, controlling for average alcohol consumption completely eliminated the effect of race on exertional heat illness risk among our smaller surveyed population. The unadjusted risk estimate comparing blacks to whites for the surveyed population was smaller than that found in the overall study population, however, suggesting that a poor sample population coupled with smaller study size may have contributed to the apparent significance of alcohol use. Nevertheless, it would be interesting to have had the ability to assess alcohol usage among the overall study population as we may have found a significant attenuation of the measured risk estimate comparing blacks to whites.

Overall, our results support the idea that race may be helpful in predicting exertional heat illnesses, heat exhaustion in particular, however gender is not. This study also suggests that alcohol consumption should be considered a potential confounder in future studies of heat illnesses and some exposures.

B. <u>Study Limitations</u>

This study has many limitations by virtue of the case-case design. A substantial positive association between race and risk of developing exertional heat illnesses may have been missed if the pseudo-control group (classic heat illnesses) is

itself associated with the exposure. Furthermore, despite our results suggesting blacks have a higher risk of exertional heat illnesses compared against classic heat illnesses, blacks could actually be protective of all heat illnesses. An example would compare the protective black vs. white odds ratios of 0.7 for exertional heat illnesses and 0.5 for classic heat illnesses. Although being black clearly shows a protective effect for both outcomes compared to being white, a case-case scenario would simply show that blacks have a higher risk of exertional heat illnesses (0.7 compared to 0.5) as our results did. A true control population (non-diseased), with an odds ratio of 1.0 would have identified the true protective effect.

Nondifferential misclassification of the exposures was minimized by our study of race and gender specifically by the simplification of the race classifications to blacks whites and others. This information was uniformly gathered upon joining the military, and misclassification would be highly unusual. However, non-differential misclassification of the outcome may have been introduced during our dichotomization of the cases by temperature. Cases were dichotomized upon the maximum daily temperature on which the heat illnesses occurred. Temperature measurements were collected by linking the date and hospital site of the incidents to the National Climatic Data Center's online data source. Proximity to climate reporting stations and knowledge of other environmental factors such as altitude, wind speed, and humidity are unknown. This could have reduced the accuracy of the temperature data resulting in nondifferential misclassification of the classic and exertional heat illnesses, thus attenuating the odds ratios.

Information bias has also been minimized by use of an administrative database where the information on the exposures and outcome were made independent of our study. Therefore, the hypothesis could not have biased subject classifications. But information bias may have been introduced if we inadvertently misclassified more exertional heat illnesses as classic based on the maximum daily temperature than we did classic heat illnesses as exertional. It has been suggested that many military heat illnesses actually occur during the cooler morning hours when heavy exercises are accomplished to avoid the heat of the day (15). By the definition of exertional heat illnesses occurring during cool temperatures with heavy exertion, this would suggest that many of the cases classified as classic heat illnesses should really be considered exertional. In this scenario we would have lost more exertional heat illnesses than actually occurs and our risk estimates would be tend to be smaller than they should.

Selection bias was largely avoided by the use of an administrative database where the subjects had little influence on their participation. However, in the covariate assessment of the health behavior variables, only subjects having completed a health behavior survey could be included in the assessment. These surveys, being voluntary in nature, give the subject the opportunity to influence the covariate assessment. It could be expected that the surveys were more often completed by soldiers that placed greater emphasis on personal health. In this case, the majority of heat illness cases linked to a health survey may report lower levels of smoking and alcohol consumption. This phenomenon would most likely be independent of the outcome because most of the surveys were probably collected prior to any heat

illness. However, we could expect an attenuation of the covariate associations with both the outcome and the exposures of interest possibly resulting in some residual confounding.

Chronic health conditions and relevant medications were considered potential risk factors for heat illnesses by the CDC (13), however they were not assessed in this study because they were not expected to be common in the study population. The importance of health status in the military has insured accurate reporting of diseases, low prevalence of chronic health problems and greatly limited the potential impact of co-morbidity on our results. Chronic health problems and some medications are assumed to be of negligible influence on our results, however it is possible that their presence could have introduced unmeasured bias.

C. **Comparison to Previous Heat Illness Studies**

Our case-only study provides an exploratory evaluation of the association between race and gender and risk of exertional heat illnesses. Some prior studies within the literature have been supported, at least partially, by our data including Kilbourne et. al., 1982 (5), Gardner et. al., 1996 (7) and Taylor et. al. 2000 (14). The results of this study were consistent with the findings of Kilbourne in that both studies reported non-significant associations in racial comparisons in relation to heatstroke (5). Our study also supported the significant association of 1.7 (1.2-2.1) reported by Gardner, for their comparison of non-white to white military heat illnesses (7). Taylor reported a 4.85 times higher rate of black to white heat mortality (14). Although our associations were not as strong, our results were similar.

Studies with results in contrast to ours include Kark et. al., 1996 (15), and Taylor et. al., 2000 (14). Kark reported military hospitalization rates suggesting a higher risk of severe heat illnesses among males, yet in our comparison of military, heat illness hospitalizations, gender associations were not statistically significant and in fact, suggested that males were less likely to suffer from exertional heat illnesses. In regards to the Alabama mortality rates, Taylor (14) also published higher rates of male heat-related mortality (RR=2.45) in direct opposition to our findings.

D. Conclusions

In closing, this study has shown little support to encourage further research into the comparison of exertional and classic heat illness defined by maximum daily temperature on the day of event. Future studies of exertional heat illnesses may expand on our analysis by exploring the ideas put forth by Kark and his colleagues, that heat illnesses are greatly influenced by environmental heat exposures of the previous day(s) (15). Race and gender should certainly by measured for potential covariate status, however this study does not support further attempts to study them as a priori risk factors. Most studies have reported only marginally significant associations for race and gender with the exception of Taylor and her colleagues, having found significant effects of race and gender on heat illness mortality (14).

CLAIMS NOT INCLUDED

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